TMT

THIRTY METER TELESCOPE

Lessons learned from the Thirty Meter Telescope site testing

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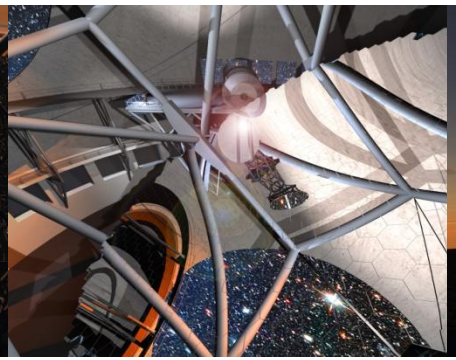
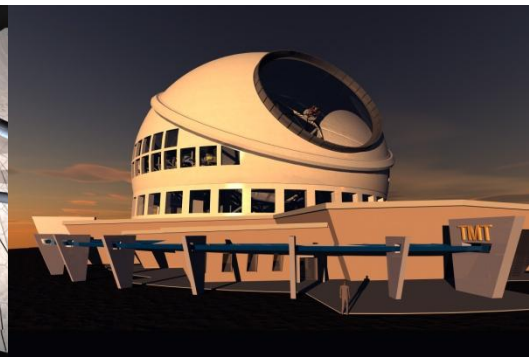
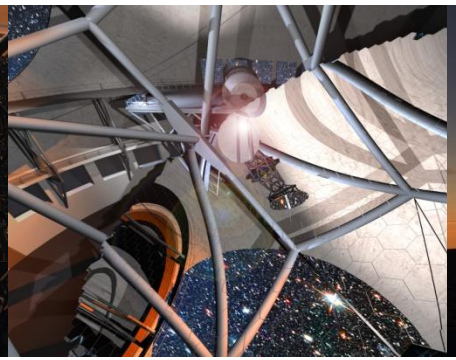
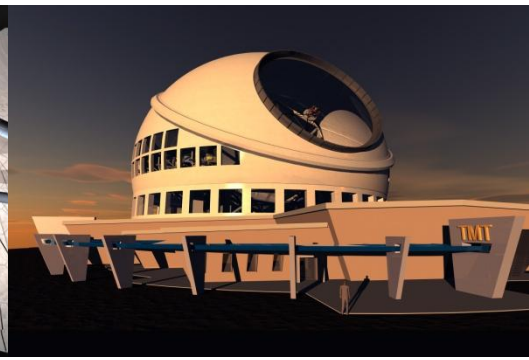



TMT

THIRTY METER TELESCOPE

- Introduction TMT and its Site testing.
- Important choice before going on site.
- Lesson learned from on-site work.
- Considerations during analysis of the data.



Some Background about the TMT Site Testing

- TMT is a 30m, segmented, Ritchey-Chretien telescope design.
- Field of view of 20’ (15’ unvignetted)
- MCAO with 2 deformable mirrors
- 3 first light instruments

Some Background about the TMT Site Testing

- Site testing started in 2004 and was concluded by the selection of Mauna Kea 13N in 2009
- Minimum of 2 years of data at each site. Comprehensive measurement of turbulence, weather conditions, PWV and more.
- Data available for download at: sitedata.tmt.org

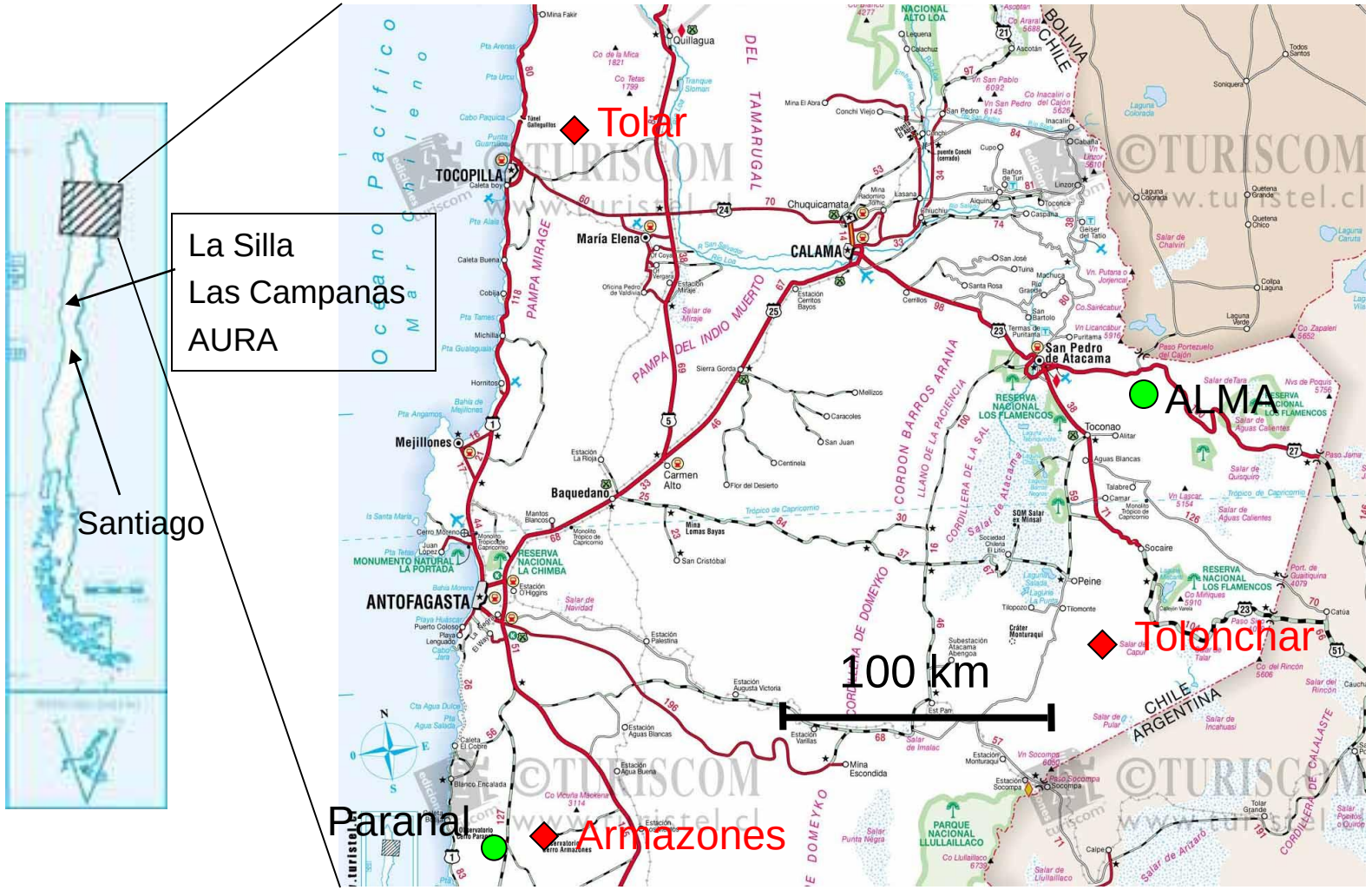
Instruments & Parameters

- Weather stations
  - temp, hum, wind, press, sol.rad, heat flux
- DIMM – seeing monitors
  - seeing, coh. time, basic photometry
- MASS – turbulence profilers
  - high-el. profiles, isopl. angle, coh. time
- SODAR – acoustic sounders
  - 20 – 800m turb/wind profiles, coh.time
- IRMA – mid-infrared radiometers
  - PWV, atm. transparency
- ASCA – Allsky cameras
  - Cloud statistics (incl. cirrus), light pollution
- Particle sensors
  - Ground level dust particle count
- Sonic anemometers
  - 7m wind, temperature, turbulence
- Simulations, satellite analysis
  - Turbulence, weather, long baseline
- Other considerations:
  - Location, elevation, geology, access, cost of construction and operation, operation model, ...

TMT's candidate sites

- Cerro Tolar (Coastal site, Chile)
- Cerro Armazones (Coastal site, Chile)
- Cerro Tolonchar (Isolated mountain, Chile)
- San Pedro Martir (Coastal site, Baja California)
- Mauna Kea 13N (Volcanic Island, Hawaii)

Chile Sites - Locations




Tolar

Armazones


Tolonchar

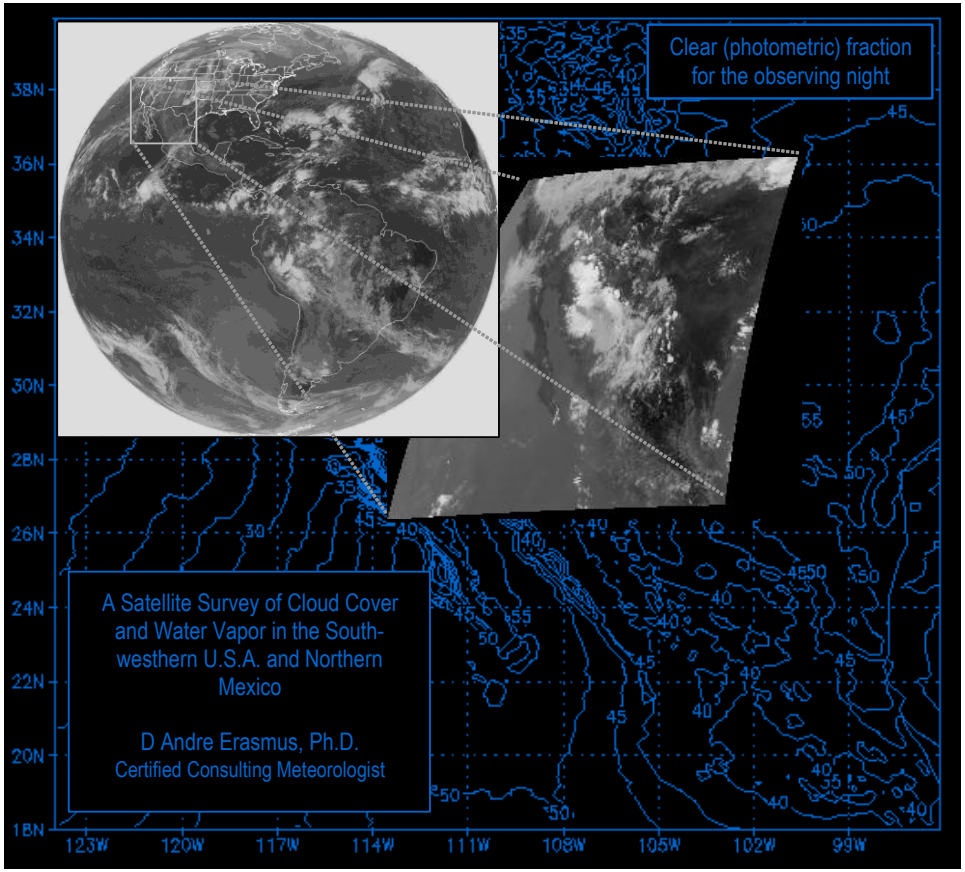
San Pedro Mártir

13 North Site

Mauna Kea 13N

Early choices 1: Strong pre-selection

- Satellite study commissioned to narrow down the study to 5 sites
- All sites confirmed by in-situ study to be good site
- After confirmation from the ground, data useful for longer time scale study.



Early choices 2: Not an Engineering project.

- “Buy, don’t build” philosophy
- Focus on gathering data and build up statistics
- Verification of instrument specifications done in the field.

Early choices 3: Standardization

Early choices 4: Redundancy

- Spares of all instrumentation:

  Allows for quick replacement and minimizes down time.

- Instrumentation with overlapping use:

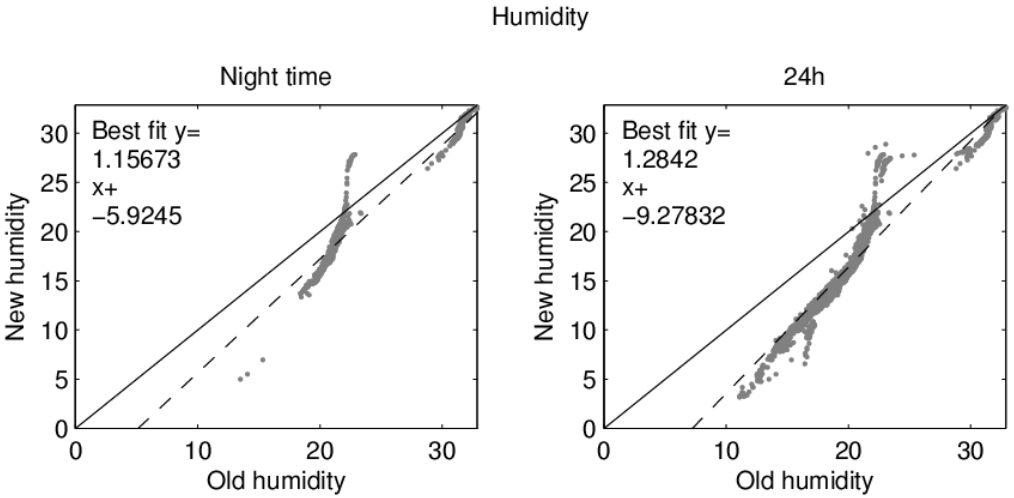
  Opportunity to cross check data and complete knowledge gaps.

- Applies to people too:

  2 people with expertise of each instrument and analysis.

Spend time on a cross-calibration campaign

Cross calibrate everything



Simultaneity of measurements

- Multi-year campaign to avoid measuring in atypical weather conditions (el nino vs la nina, Bolivian winter, etc..)
- Maximize overlapping time of campaigns between sites (understand local effects and removes potential trends)

Telescope choice

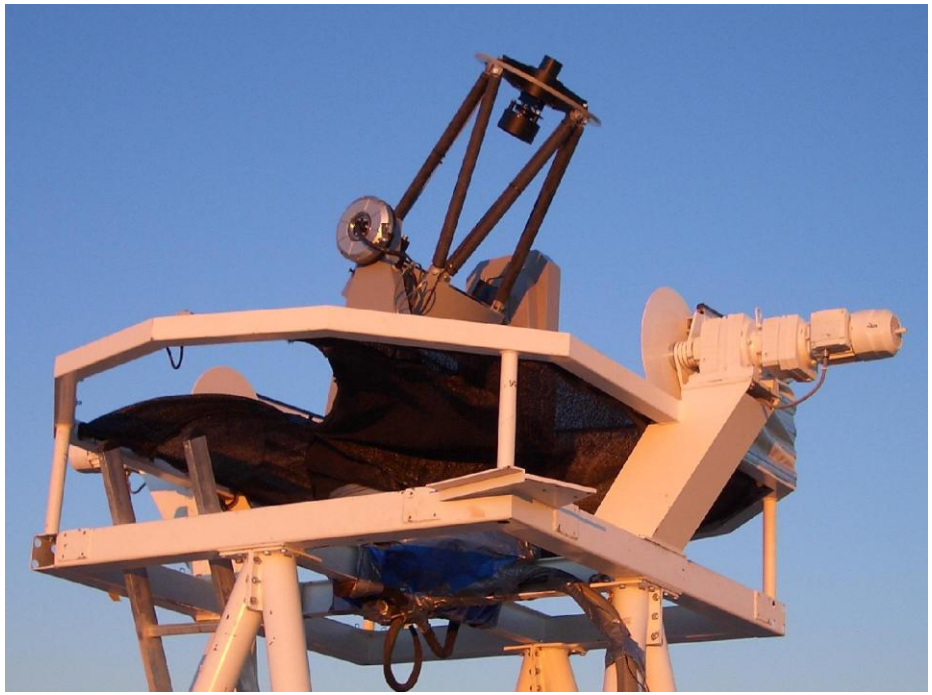
- Open dome Design: minimize local turbulence
- Open tube:

  No tube seeing, smaller footprint
- Robust telescope:

  Observe in most wind conditions
- Stiff tower:

  Keep vibrations to a minimum
- Active focus:

  Allows better and remote alignment checks



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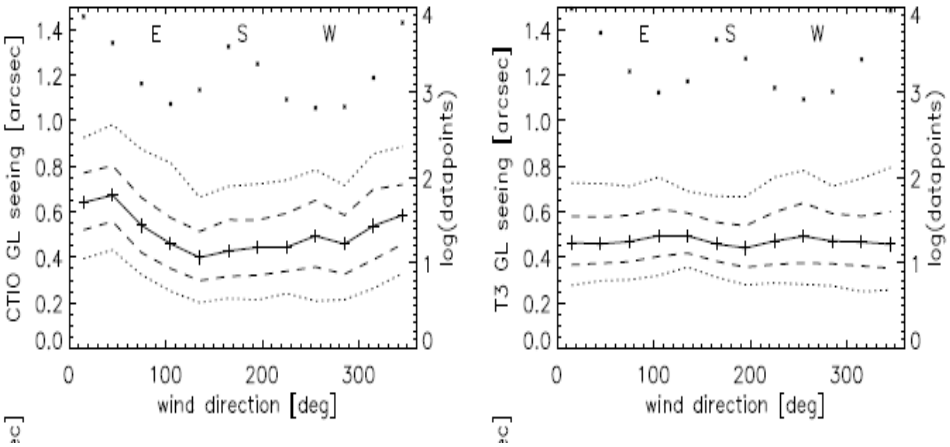

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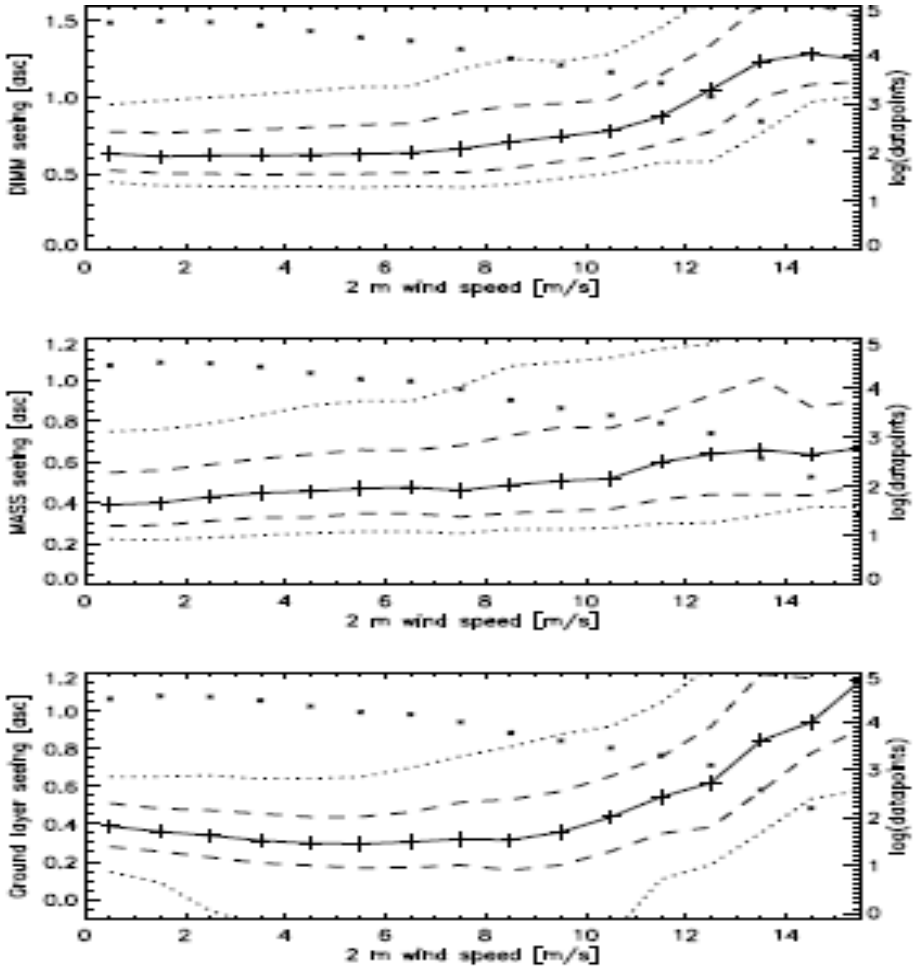


Hardware: Wind speed sensors

Software

Fully automatic, robotic system, but constantly connected via Internet. Full manual remote operation and a lot of remote trouble-shooting and control are possible

Example of the Site Status Overview web page

TMT Site Status Overview

Telescope reports

Site	T1	T2	T3	T4	T5	T6
Update Time	2006-12-01 21:09:06	2006-12-01 21:09:04	2006-12-01 21:09:05	2006-12-01 21:09:05	2006-12-01 21:09:05	2006-12-01 21:09:05
Evening Twilight	2006-12-02 00:01:00	2006-12-02 00:09:00	2006-12-01 23:58:00	2006-12-02 01:30:00	2006-12-02 01:32:00	2006-12-01 04:24:00
Morning Twilight	2006-12-02 09:14:00	2006-12-02 09:06:00	2006-12-02 08:59:00	2006-12-02 13:48:00	2006-12-02 13:57:00	2006-12-01 16:13:00
NREF	Present	Present	Not Present	Not Present	Not Present	Present
Ops Mode	Stopped	Stopped	Stopped	Stopped	Stopped	Stopped
Dome	UNKNOWN	UNKNOWN	Between	Closed	Between	Between
Star						
Altitude	-99999:00:00	-99999:00:00	9:59:54	9:59:57	9:59:56	9:59:54
Azimuth	-99999:00:00	-99999:00:00	119:59:59	89:59:59	0:00:00	-175:48:20
Focus Position	-99999	-99999	15.671	10.629	14.426	13.561
Cabinet	Good	Good	Good	Good	Good	Good
Altitude Axis	Warning!	Warning!	Warning!	Good	Warning!	Good
Azimuth Axis	Warning!	Warning!	Warning!	Good	Warning!	Warning!
Focus Axis	Warning!	Warning!	Warning!	Good	Warning!	Good

Weather reports

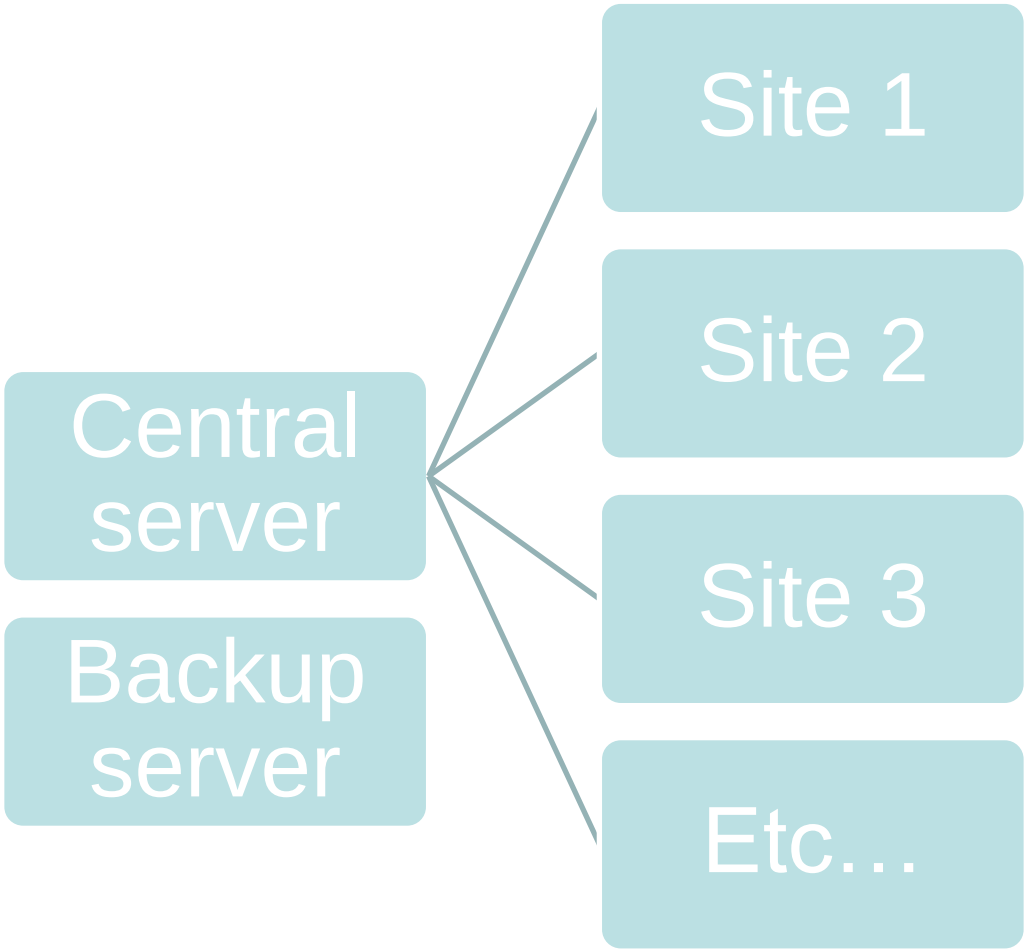
Site	Time (UT)	Temp °C	Humid %	Precip %	Dew °C	Wind Spd km/h	Wind Dir degrees	Press hPa	Solar Rad W/m^2	Heat Flow W/m^2	Net Rad W/m^2	Soil T °C	Batt V
T1	2006-12-01 21:10:06	16.306	14.17	0.00	-11.098	13.250	4.03	777.78	444.8	----	----	19.754	6.66
T2	2006-12-01 21:09:05	14.362	22.28	0.00	-6.927	16.920	261.08	711.16	491.4	32.6	279.9	----	6.11
T3	2006-12-01 21:08:06	10.490	20.94	0.00	-10.941	39.210	300.95	600.22	453.2	-14.8	257.0	----	6.49
T4	2006-12-01 21:08:05	9.900	23.33	0.00	-10.079	0.000	8.41	733.18	645.9	2314.7	----	----	0.07
T5	2006-12-01 21:08:06	16.202	20.11	0.00	-6.728	4.690	5.16	832.63	553.9	----	----	----	6.73
T6	2006-12-01 21:08:05	4.156	76.51	0.00	0.391	14.510	163.58	609.22	521.5	71.6	348.8	----	6.77

Computer and network elements status

Site	T1	T2	T3	T4	T5	T6
Computers	Good	Good	Good	Good	Good	Good
NPS	Good	Good	Good	Good	Good	Good
Webcams	Good	Good	Good	Good	Good	Good

Software management and data access

- Software updated on the central server and pushed to all sites to avoid discrepancies between sites
- Daily backup of data and logs to central server and backup server
- Database accessible online, formatted for quick re- analysis



Analysis coherence and verification

- Analysis routine started early in the program.
- Each analysis done by two people. Allows verification of code and results but also highlighted different methods for the analysis and filtering of the data.
- Reports written with Matlab…

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Cloud Cover Definition

First idea: Use geometrical cloud coverage, averaged in both space and time.

Problem: Not a useful quantity for TMT as illustrated using the following examples (see also the images on the next slides)

- Sky entirely covered first half of the night, entirely clear second half: **50% coverage**
- Bands of clouds moving through every 15 minutes, with equally long clear gaps in between: **50% coverage**
- Small broken clouds covering half of the sky at any time during the night: **50% coverage**

All these cases give the same geometrical coverage, but are very different in their usefulness for TMT. This is not sufficient. Need other definition of cloud cover.

Cloud Cover Definition

Geometrical coverage is not a useful definition. Other possibilities:

- Cut night into one (half, two, ...?) hour segments. Class segment as:
  - Photometric: no clouds within 65^{o} of zenith during entire hour
  - Spectroscopic: thin or broken clouds present
  - Unusable: continuous thick clouds
- Define a “cloud coherence time”:
  - Average time during which conditions remain constant
  - Problem: obtaining a quantitative estimate
- Others?

ASCA Cloud Cover Analysis

So how do we do it in practice? Options:

- Visual analysis of ASCA images/movies to get cloud cover
  - Pros:
    - "Simple" method; easy to implement
  - Cons:
    - How quantitative is it?
    - Somebody has to watch all the movies
- Automated photometry software package
  - Pros:
    - Quantitative analysis of cloud cover, time constant, transparency
    - High time and spatial resolution opacity measurements
  - Cons:
    - Huge software development effort needed (not possible for us and LSST effort will probably not be useful for TMT)

Fin…

Acknowledgement

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